PROJECT PROGRESS REPORT

PREPARED FOR THE ALASKA ENERGY AUTHORITY BY
THE ALASKA CENTER FOR ENERGY AND POWER

PROJECT TITLE: *Round 1:* Emerging Energy Technology Fund – Data Collection

REPORTING PERIOD: 1st Quarter 2015

DATE OF REPORT: April 21, 2015

GRANT RECIPIENT:
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EETF Round 1 Projects

Project #003 – Alaska Division of Forestry, Biomass Reforestation

No new information is available regarding this project, and no site visit or survivability assessment was possible during the winter months. The Department of Forestry has indicated it will survey the winter survival this spring and summer. More information will be available in future quarterly reports.

Project #006 – Arctic Sun, Arctic Thermal Shutters and Doors

Arctic Sun has transmitted over 200 data files to ACEP associated with their thermal shutter test chamber. These data are stored in a proprietary HOBOWare format and detail the test chamber temperature conditions as well as ambient weather and power requirements. In the next quarter, ACEP intends to export these data into a data analysis program capable of handling large quantities of data such as National Instrument's DIADem. Once the data is imported, ACEP will conduct a detailed analysis of the performance of the thermal shutters.

Project #009 – Genesis – Ultra-Efficient Generators and Diesel-Electric Propulsion

Genesis Machining continues to make progress on their inverter. They have designed and received custom circuit boards for their TRL7 device. Early indications are that these boards fit as anticipated and are currently being populated with their surface-mount components. Genesis has asked that pictures not be shared as they consider these boards proprietary. As the inverter is under construction, there are no data to share.

Project #026 – Cold Climate Housing Research Center (CCHRC), Ground Source Heat Pump (GSHP)

The ground source heat pump at the Cold Climate Research Center in Fairbanks continues to operate as expected, logging Coefficient of Performance (COP) values between 3 and 4 with higher values occurring earlier in the year and lower values occurring later in the year when the ground has cooled. Table 1 outlines the calculated COP values since October.

Table 1. CCHRC GSHP COP values since October 2014

Month	Avg COP	Standard Deviation
Oct-14	3.89	0.191
Nov-14	3.68	0.165
Dec-14	3.64	0.164
Jan-15	3.28	0.224
Feb-15	3.22	0.229
Mar-15	3.29	0.195

The assumed COP of a standard electric resistance heater is 1. Typically, calculation of the COP from a heat pump does not take into account the electric loads of the circulation pumps. However, adding these electric loads to the load of the heat pump as part of the COP calculation can serve as a useful measure with which to compare the efficiency of the heat pump to basic baseboard electric resistance heating. The difference between straight COP and COP calculated by adding the sum of circulation pump energy is 0.65, which would be subtracted from the values above to get a COP that accounts for circulation pump energy. These adjusted COP levels are still higher than the COP of basic electric resistance.

Project #028 – University of Alaska Fairbanks (UAF), Organic Rankine Cycle (ORC)

The ORC project has been stymied by the recent explosion of the polycarbonate evaporator cylinder. Leak and durability tests with pressured air at 150 psia were conducted before the introduction of R-134a into the system. Design modifications and replacement materials will be discussed during the next quarter.

Project #029 – University of Alaska Fairbanks, Exhaust Thimble

The University of Alaska Fairbanks received an EETF grant to develop an exhaust thimble that can be safely installed without the air gap and air leak associated with standard thimbles. The instrumentation for the exhaust thimble was intended primarily to provide model verification. The secondary intent was to demonstrate that the thimble did not present a fire hazard. As such, this analysis deals exclusively with the temperatures at the interface of the thimble and the building.

UAF designed and built four thimbles ranging from 2 inches to 10 inches and tested them in both summer and winter conditions. Additionally, these thimbles were tested both with their internal passages open and with their internal passages occluded to simulate a worst-case scenario.

Figures 1 and 2 show the results of the summer tests.

Figure 1: Roof vs. exhaust temperature during summer test period with thimble fully occluded

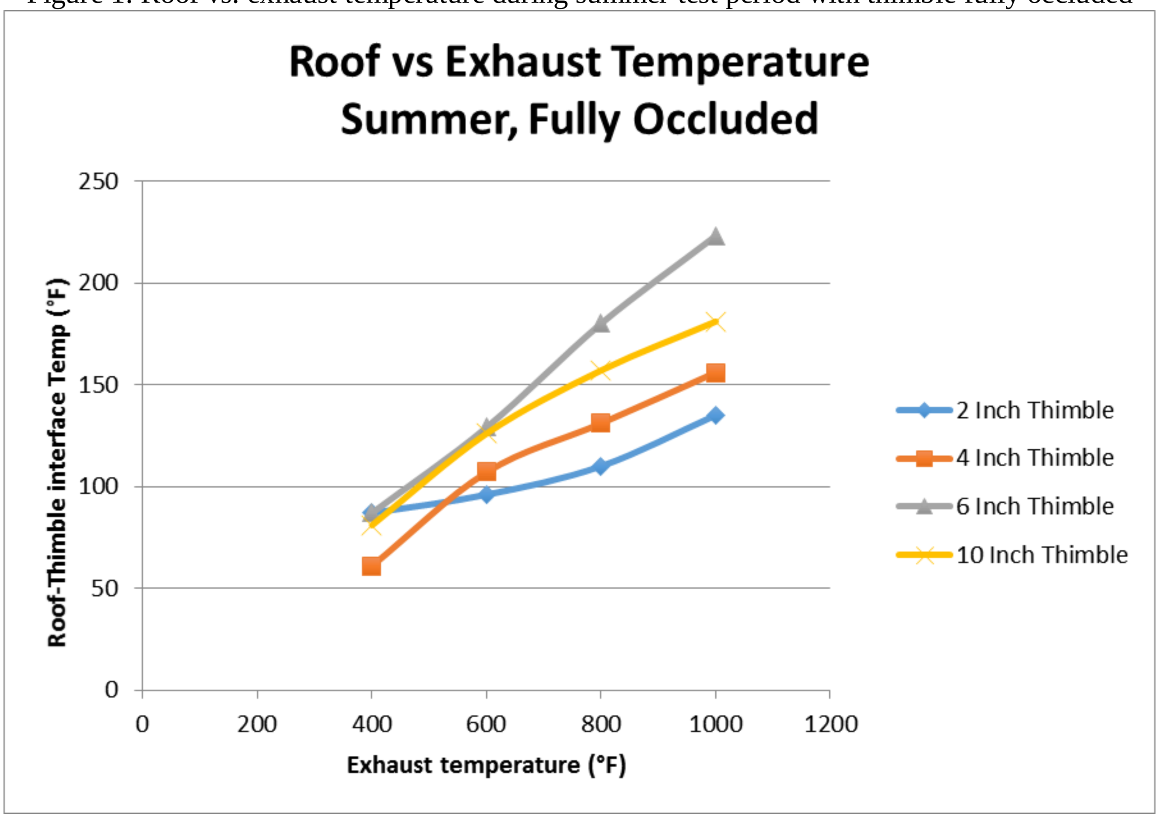
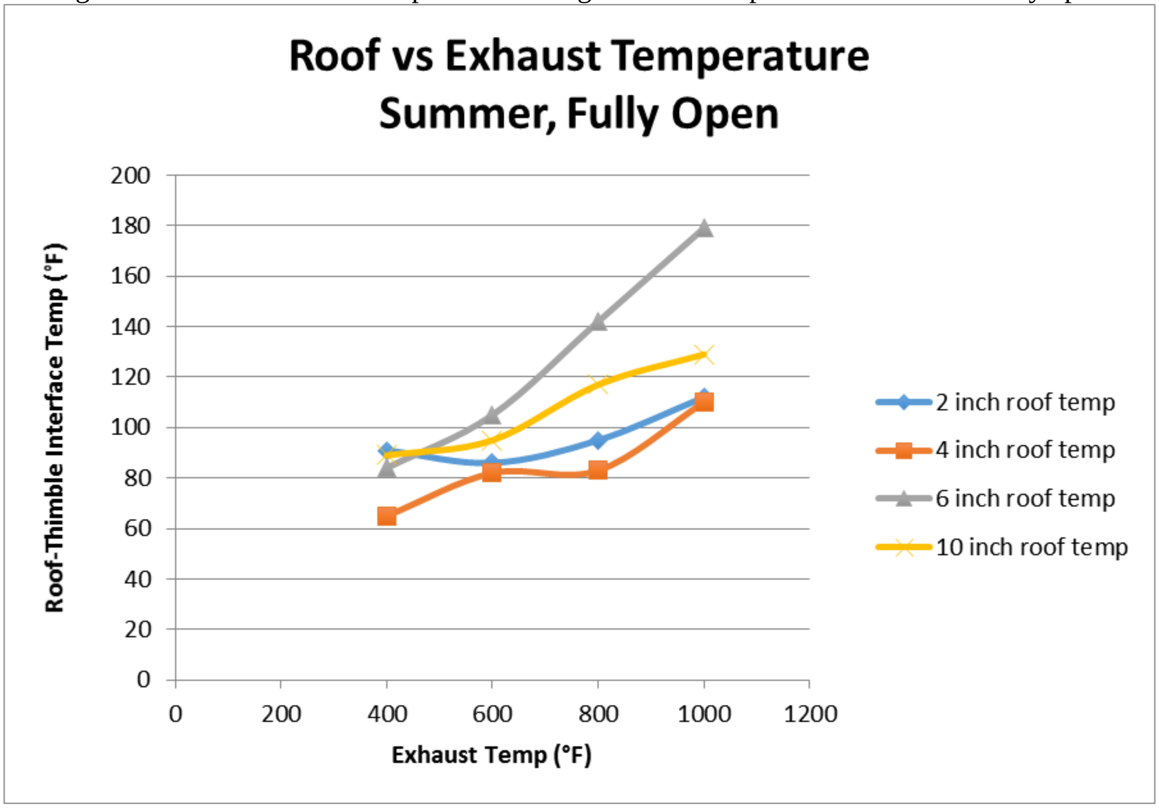


Figure 2: Roof vs. exhaust temperature during summer test period with thimble fully open



Interestingly, the 6-inch thimble was the worst performer in terms of roof-thimble interface temperature (i.e., the roof-thimble interface temperature was the highest). Details of the construction were not provided so no explanation is available for this trend.

An exhaust temperature of 1000°F is abnormal and extremely high. Typical exhaust temperatures are 400-600 °F. Nonetheless, at an exhaust temperature of 1000°F, the fully occluded 6-inch thimble had the highest, but still acceptable, roof-thimble interface temperature of 223°F. At typical exhaust temperatures, all thimbles performed well and had interface temperatures in the range of 65-126 °F.

Analysis of the winter data is not provided but it is noted that, as expected, interface temperatures are lower in winter than in summer. Activities next quarter include final data analysis, and outlining steps toward a final report.

Project #035 – Altaeros, Airborne Wind Turbine

Project activities this quarter have been minimal. ACEP continues to monitor project status.

Project #037- Oceana, Hydrokinetics

Engineers with Oceana Hydrokinetics traveled to Fairbanks in March to dismantle their turbine and assess component wear after last summer's testing in the Tanana River. Inspection of the turbine revealed there was damage to the water-lubricated bearings. During the initial design process, engineers realized these bearings were a place of potential weakness since the waters of the Tanana River have a very high silt load, and they used several types of bearings to test the wear characteristics. ACEP engineers observed that the ceramic bearings were severely worn. The diamond bearings fared much better. Oceana researchers did not allow pictures of the bearing wear or the inside of the turbine; however, the Figure 3 shows the dismantlement process.

Figure 3: Dismantlement of the Oceana hydrokinetic turbine

Data from last summer's Tanana River testing was again requested from Oceana. Oceana indicated that over 600 data files were collected and the company is currently working to process the data into a usable format. This analysis should be available in the next quarterly report. Activities next quarter include outlining steps toward a final report.

<u>Project #043 – Ocean Renewable Power Corporation (ORPC), Hydrokinetics</u>

ACEP continues to be in touch with ORPC and the University of Washington to obtain data and sheer information related to last summer's testing in Igiugig. The University of Washington will release their modeling techniques for ACEP to review when they publish their paper describing the methodology. This was expected to have been done by now but should occur shortly according to UW personnel. Activities next quarter include outlining steps toward a final report.

<u>Project #058 – Boschma Research Inc. (BRI), Hydrokinetics</u>

There are no further activities to report relating to the BRI hydrokinetic turbine testing since last quarter. Activities next quarter include outlining steps toward a final report.

<u>Project #045 – Hatch, Flywheel</u>

Hatch, LLC tested its flywheel at ACEP's Power Systems Integration lab January 5th-14th, 2015. The data from these tests was transmitted to ACEP for verification and analysis. These tests were used to verify the efficiency and response of the flywheel system as detailed in Table 2.

Table 2: Efficiency and response of Hatch flywheel

Date	Iteration	AEA Description
150105	2	200kW efficiency test
150105	3	150kW efficiency test
150105	4	100kW efficiency test
150105	5	50kW efficiency test
150105	6	10kW efficiency test
150106	5	460Hz efficiency and capacity test (extended FW range)
150114	5	VSI-ISO block Load 50kW Limits
150114	6	VSI-ISO block Load 100kW Limits
150114	7	VSI-ISO block Load 200kW Limits

The efficiency tests involved discharging and then charging the flywheel and measuring the energy lost in the process. For these tests, the flywheel started at 36,000 rpm and was discharged, thereby slowing the flywheel. Energy was then added to bring the flywheel back to 36,000rpm. Figure 4 shows the power curve for the 200kW efficiency test. Figure 5 shows data from the same test but in terms of energy rather than power. As can be seen, there is more energy into the system than out of the system and the ratio of these terms is an indication of the flywheel system efficiency during this test. In this case, for the 200kW test, the flywheel system has a turn-around efficiency of 60.3%. It is noted that these tests happened over a short time interval. This interval should work to minimize the effect of standby losses.

Figure 4: Power vs. time for 200 kW Hatch flywheel efficiency test

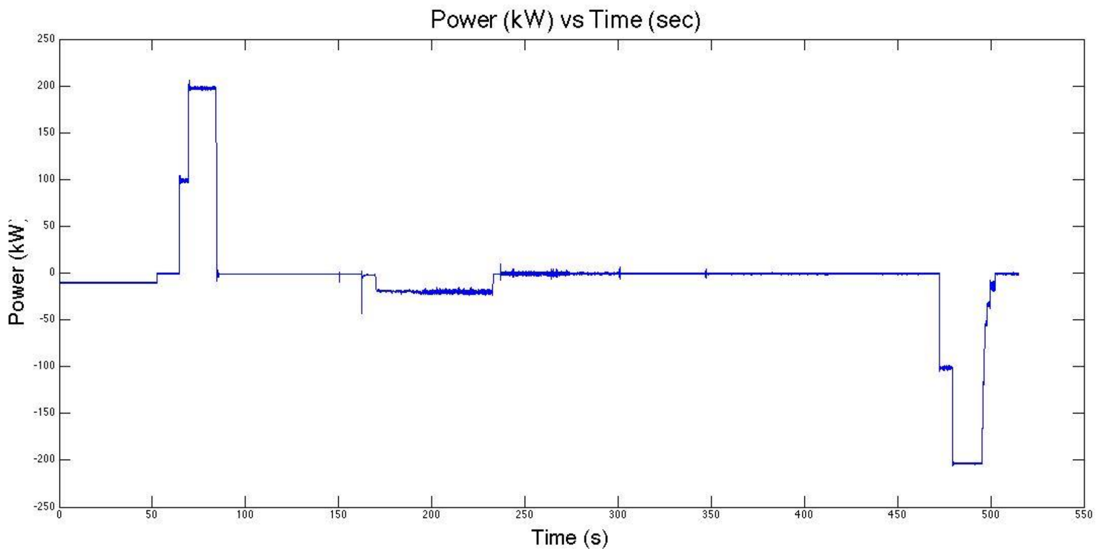
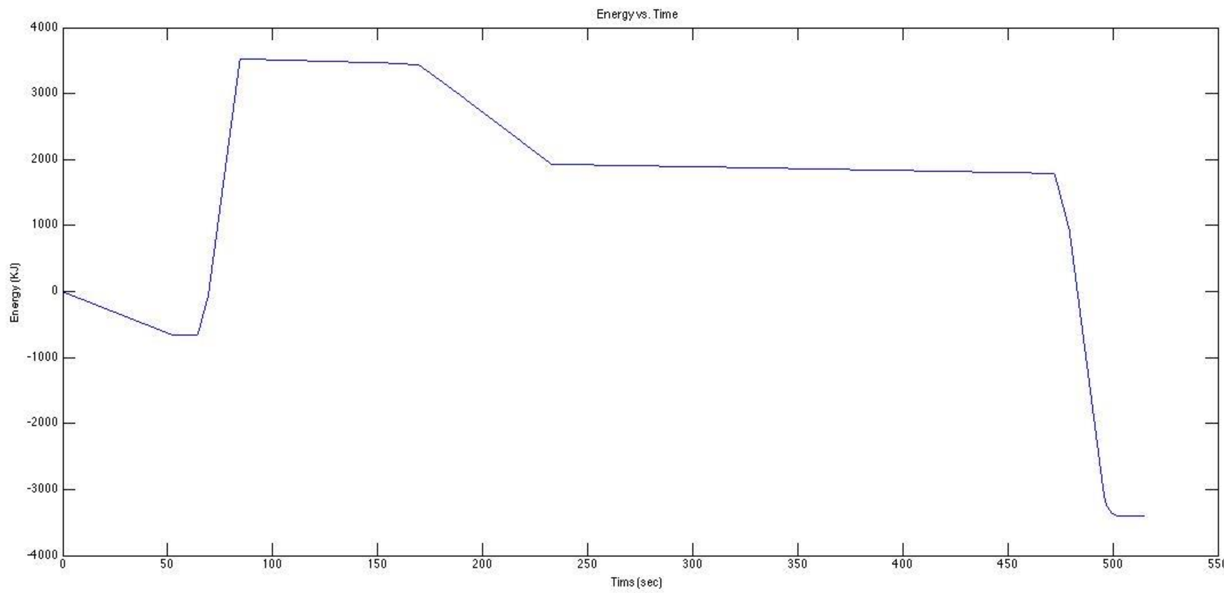
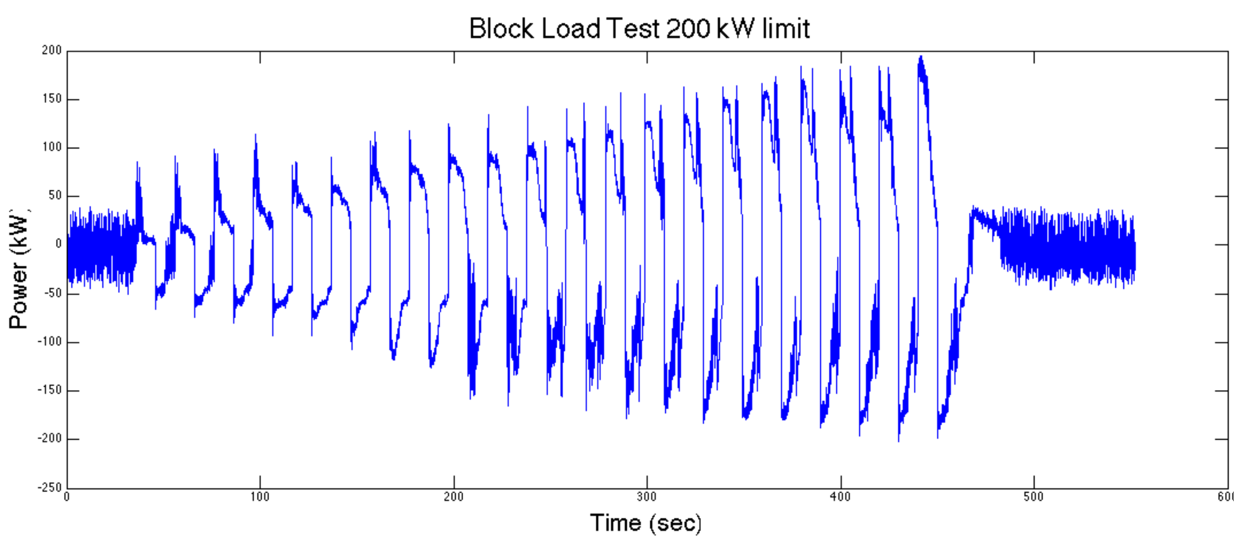


Figure 5: Energy vs. time for 200 kW Hatch flywheel efficiency test



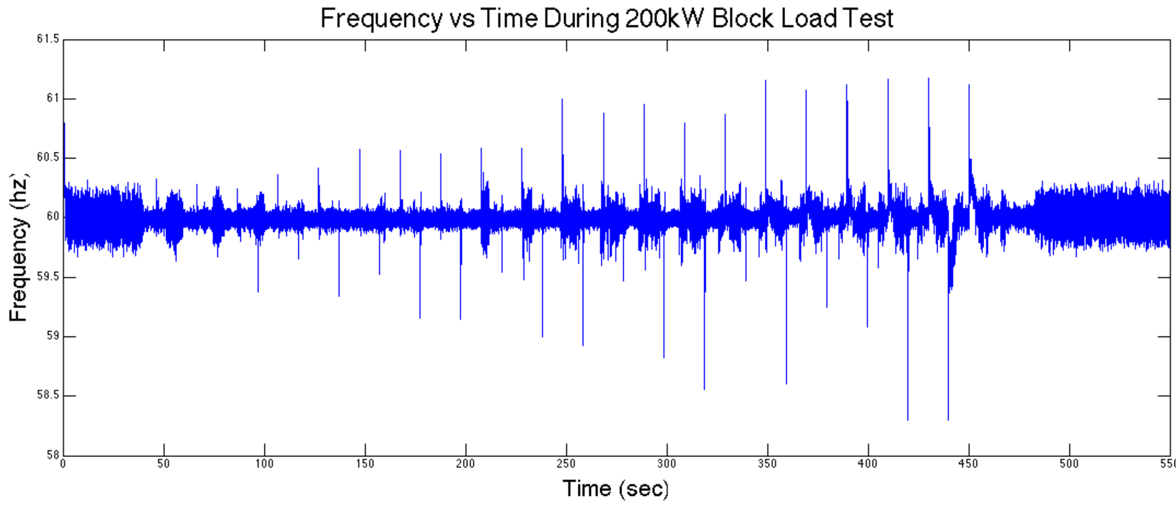
The VSI-ISO Block Load tests involved subjecting the flywheel system to alternating charge-discharge cycles and observing the response. The power curve of the 200 kW test is shown in Figure 6.

Figure 6: Power vs. time for 200 kW Hatch flywheel Block Load test



Of note is the resulting frequency of the electrical output shown in Figure 7. Rather than a stable 60 Hz, the frequency shows spikes up to 61.4 hz and sags down to 58.3 hz.

Figure 7: Frequency vs. time during 200 kW Hatch flywheel Block Load test



While this frequency deviation is not desirable, it is not cause for concern. The 50kW and 100kW block load test showed similar results. Activities next quarter include outlining steps toward a final report.

Project #061 – Marsh Creek, Various Speed Diesel-Electric Generation

Under the EETF program, Marsh Creek, LLC was awarded a grant to test an innovative coupling system that will allow a diesel-electric generator to operate at two different set points - 1200 rpm and 1800 rpm - while the generator remains at a constant speed. Diesels are typically must efficient when they are at maximum power for a given rpm. By shifting to a lower rpm when electrical demand is down, the intent is that there will be a corresponding improvement in efficiency. Changing engine rpm while maintaining a constant generator speed is a non-trivial task and can have impacts on power quality.

On March 9th, 2015, ACEP personnel Tom Johnson, Chris Pike and Erin Whitney conducted a site visit to Marsh Creek in Anchorage, AK. While there, they met with Vladimir Leonov and Maggie McKay and discussed the Flux Drive instrumentation and testing protocol.

Marsh Creek designed, built, and instrumented a Flux Drive system shown in Figures 8 and 9. The instrumentation system, shown in figures 10 and 11, is Modbus based and, in addition to monitoring the J1939 engine parameters, has a scale under the day-tank and external flow meters for fuel flow. These external flow meters are outfitted on both the fuel supply and return lines. They are of the paddle-wheel variety and shown below in Figure 12. While these meters have poor absolute accuracy, Marsh Creek is comparing relative values which should be adequate to demonstrate any efficiency improvement. These fuel lines are not instrumented with temperature sensors. As such, properties such as viscosity change that may affect the flow meters will not be accounted for.

The Modbus system has a sample rate of 1 Hz. Since 1 Hz is insufficient for capturing anomalous power quality events, Marsh Creek is using a scope to capture high frequency data during the shift from 1800 rpm to 1200 rpm and vice versa. Marsh Creek stated that while they expect some deviation from a perfect 60 Hz sine wave, they expect power quality to remain acceptable as defined by the current regulatory standards.

Marsh Creek's testing protocol requires that they complete base-line testing at multiple power levels at 1800 rpm. They intend to hold each power level for 15 minutes to allow the engine settle into steady state. Once baseline testing is completed, they will then test with the flux drive engaged.
Upon completion of testing, Marsh creek will make their data available to ACEP for review and analysis.

Figure 8: Marsh Creek Flux Drive system

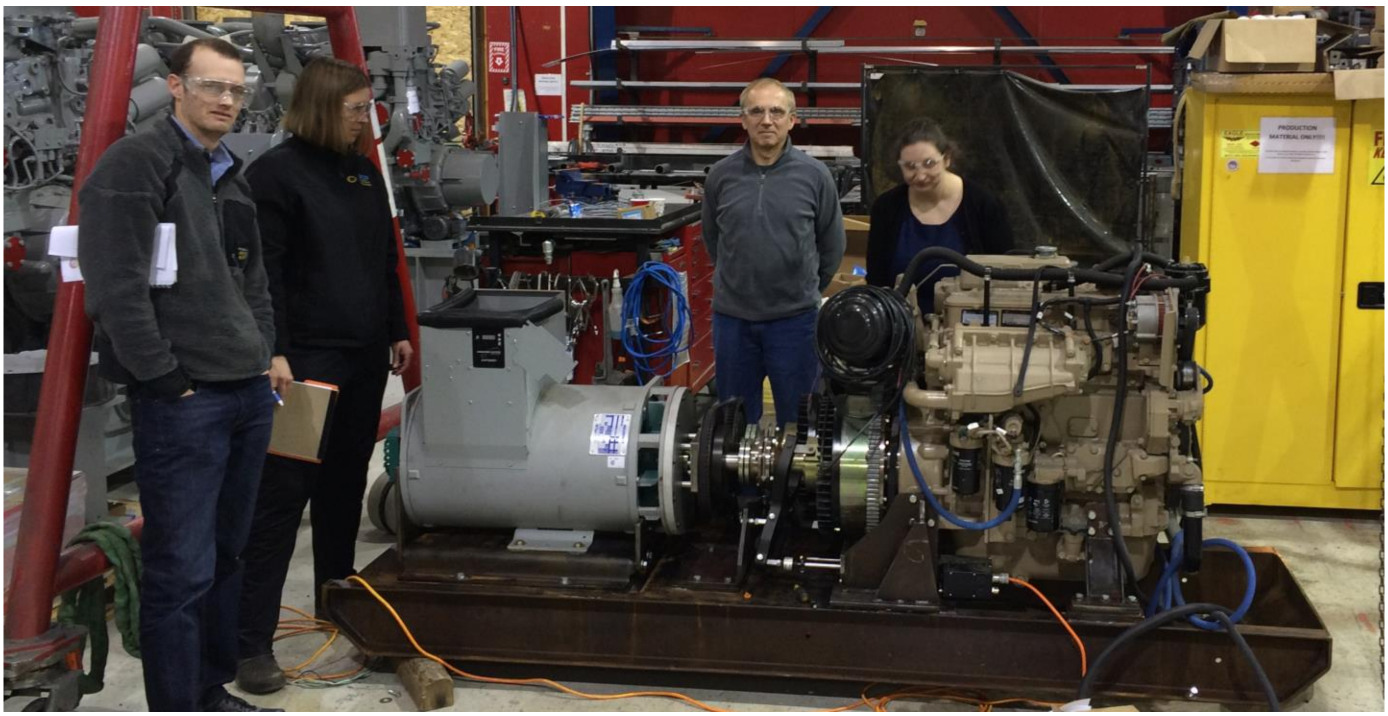


Figure 9: Close-up view of Marsh Creek Flux Drive components

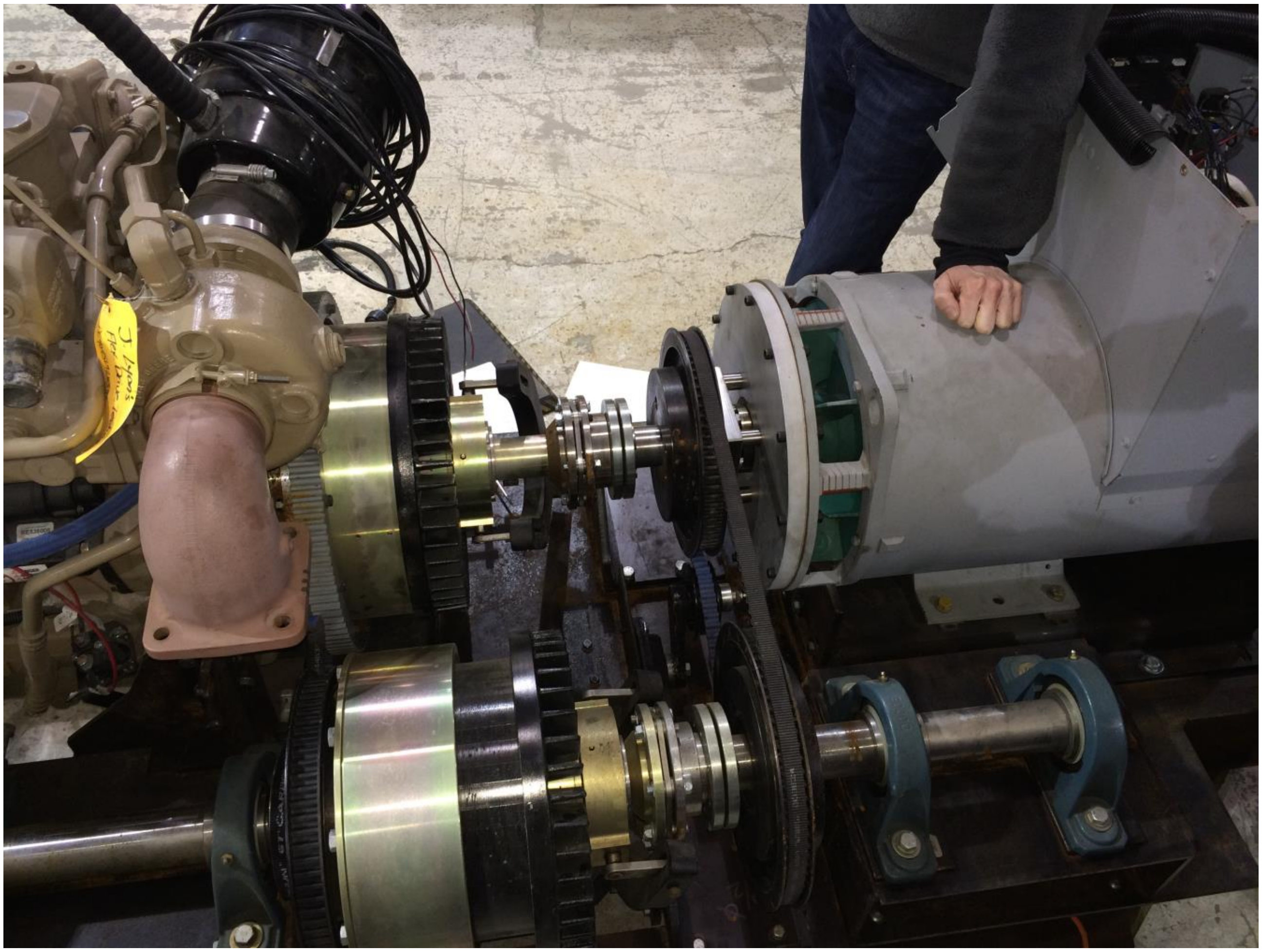


Figure 10: Modbus instrumentation system

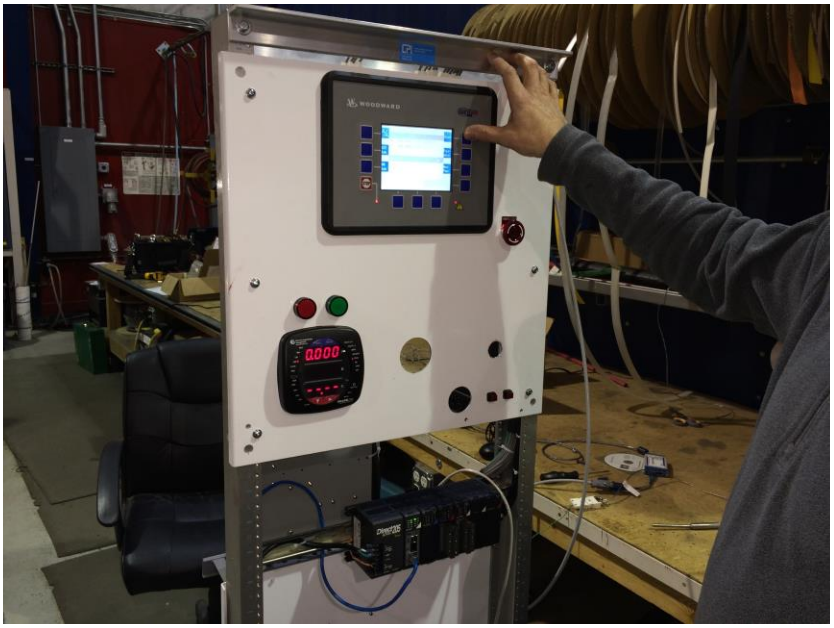
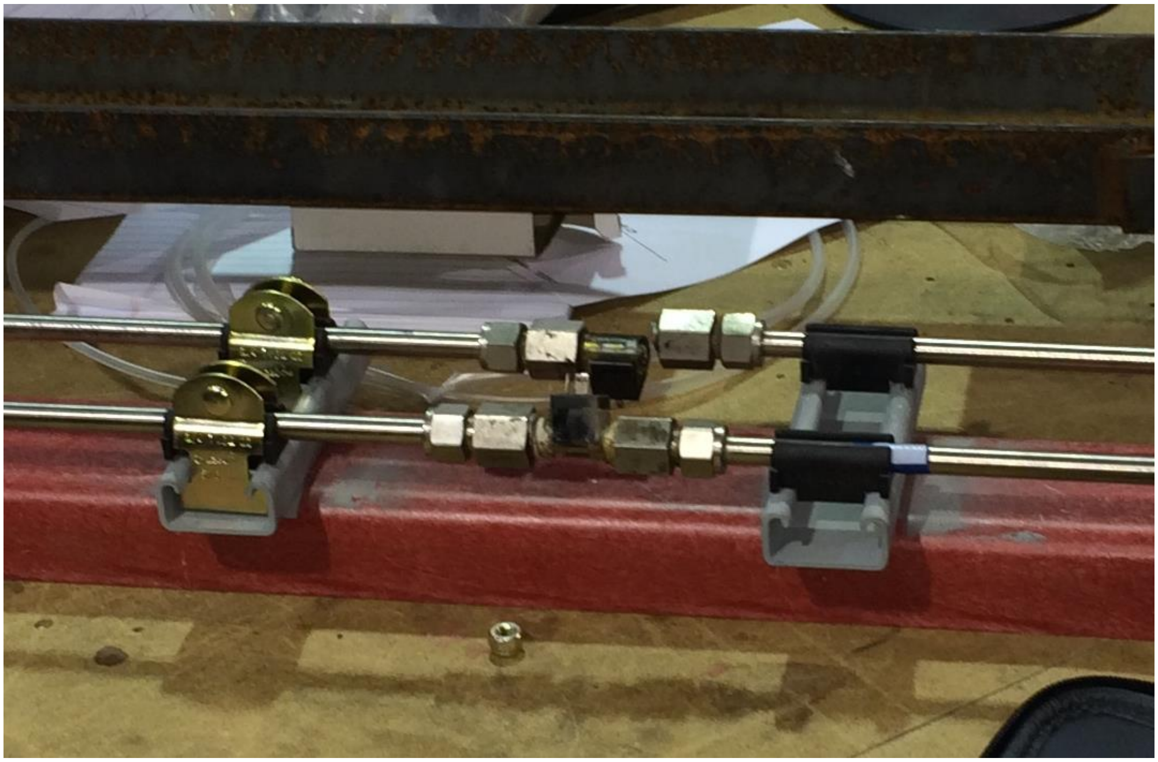


Figure 11: Modbus instrumentation system

Figure 12: Supply and return flow meters



Project #049 – Intelligent Energy Systems (IES), Self-Regulated Grid &

ACEP staff communicated with Ben Bay of IES via telephone for a project status update on 3/26/2015. Ben indicated that the installation of the SRG system was competed in January. The first test took place soon thereafter during an approximately 14 MPH wind event. The generator set point was changed to mimic a higher wind situation. During the first test, the system experienced major frequency oscillations. As they added more stoves to the system, up to a total of about 14 stoves, the frequency oscillations got worse. At 60.25 Hz the load regulator activated to stabilize the frequency.

On examination it was discovered that the programming on the Steffas stoves was only set to react every second. This was insufficient to allow for the stoves to regulate village power quality during high wind events. Discussions with Steffas have revealed that the system programming structure is based around this one second reaction timing and changing this is not trivial. Discussions between IES and Steffas are ongoing. No data have been received by ACEP related to this project.

Project #051 – Intelligent Energy Systems (IES), Wind-Diesel-Battery Hybrid System

ACEP staff communicated with Ben Bay of IES via telephone for a project status update on 3/26/2015. Ben indicated that the challenge with data collection in Kwig has not been the collection of the data, but rather the man hours necessary to go back through the data and look for transient events. Ben indicated that because there have been no power quality (PQ) issues, the meter does not trigger to record and flag the data. It seems as though a script could be written to flag the 5 seconds around the time when the generator shuts off; ACEP personnel will pursue this option during the next quarter.

The BESS system is back up and running. There are three working generators in the village, and they are hoping for a fourth soon. The major pump on the school now has a soft start. According to Ben, it was interesting to note that before the soft start was installed, the BESS was able to absorb the load fluctuations while the generators were not, resulting in PQ issues.

The possibility of using an Elspec or similar meter was discussed, and Ben didn't see the point since he indicated they are capturing the data. He said they also have a Fluke 435 that they can use for consumer side PQ monitoring.

ACEP will conduct a site visit for both IES projects during the next quarter and continue to work towards the goal of\ more consistent data collection.